Comparison of Direct and Indirect Blood Pressure Measurements in Anesthetized Dogs

Malcolm J. Gains, Krystyna M. Grodecki, Robert M. Jacobs, Doris Dyson, and Robert A. Foster

ABSTRACT

The precision and accuracy of an indirect oscillometric blood pressure measurement technique (Dinamap 8100) was assessed in 11 anesthetized Beagle dogs weighing 8 to 11.5 kg. Direct blood pressure measurements were made by catheterization of the lingual artery, and simultaneous indirect measurements were determined by placing a cuff over the median artery (midradial area). Blood pressure measurements at 2 different planes of anesthesia (light and deep) were recorded in triplicate. At a light plane of anesthesia, the Dinamap 8100 underestimated diastolic and mean arterial pressure, and at a deep anesthetic plane overestimated systolic pressure. The indirect technique had good repeatability of systolic pressures. Regression analysis for the 2 techniques showed excellent correlation (r = 0.93). The results indicate that the indirect oscillometric blood pressure measurement technique provides a good estimate of systolic, diastolic, and mean arterial pressure in dogs weighing 8–11.5 kg.

RÉSUMÉ

Une évaluation de la précision et de l'exactitude de la mesure de la pression sanguine par la méthode indirecte d'oscillométrie (Dinamap 8100) a été faite chez 11 chiens anesthésiés de race Beagle pesant de 8 à 11,5 kg. La cathétérisation de l'artère linguale permettait d'effectuer des mesures directes de la pression sanguine de façon simultanée aux mesures indirectes effectuées en plaçant un manchon recouvrant l'artère médiane. Des données en trois exemplaires des mesures de la pression sanguine ont été enregistrées sous anesthésie superficielle et profonde. Sous anesthésie superficielle, le Dinamap 8100 a sous-evalué la pression artérielle moyenne et la pression diastolique, alors que sous anesthésie profonde, il a surévalué la pression systolique. Une bonne répétabilité des mesures de la pression systolique était notée avec la méthode indirecte, et les analyses de régression ont montré une excellente corrélation entre les deux méthodes de mesure (r = 0,93). Les résultats démontrent que la technique d'oscillométrie comme mesure indirecte de la pression sanguine fournie une bonne estimation de la pression artielle moyenne, de la pression systolique et de la pression diastolique chez les chiens pesant de 8 à 11,5 kg.

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Accurate blood pressure monitoring is often required during surgical and research procedures. Direct blood pressure measurement via intraarterial catheterization provides the most reliable data (1,2); however, it has several drawbacks. Intraarterial catheterization is invasive and therefore carries the inherent risk of sepsis, as well as difficulties with implanted materials and catheter occlusion. Intraarterial catheterization is also technically demanding, especially in very small animals, and painful in nonanesthetized subjects. The technique is not amenable to chronic sampling since maintenance of catheters can be difficult. For these reasons, many researchers and clinicians prefer indirect techniques of blood pressure determination.

Noninvasive, indirect techniques do require that the animal be kept still for 20–30 s while the measurement is taken. Indirect techniques require a relatively large superficial artery on a distal extremity that may be occluded by the application of a pressure cuff. The availability of such vessels is another factor limiting indirect monitor usage. The variability in limb size and shape between various sizes of dogs may also reduce the researchers' confidence in this technique. The major concern, however, focuses on the accuracy and precision of indirect measurements. Our study was undertaken to compare direct and indirect measurements of systolic, diastolic, and mean arterial pressures over a range of depths of anesthesia and, hence, blood pressures, in small dogs (<12 kg).

Eleven Beagle dogs, ranging from 8–11.5 kg bodyweight, were used. The dogs were maintained in accordance with Canadian Council on Animal Care guidelines (3). The dogs were anesthetized using 1 of 2 regimes, to which they had been randomly assigned. One group (n = 7) was premedicated with acetylpromazine given intramuscularly (IM) at 0.1 mg/kg, then anesthesia was induced with thiopental given intravenously (IV) at 10–15 mg/kg. Following endotracheal intubation, anesthesia was maintained with halothane delivered in a circle-type anesthetic machine (Ohio Medical Products, Fluotec MKIII, Fraser Harlake, Orchard Park, New York). The 2nd group (n = 4) received butorphanol given IM at 0.2 mg/kg as a premedication, followed by thiopental

Department of Pathology (Gains, Grodecki, Foster, Jacobs) and Department of Clinical Studies (Dyson), Ontario Veterinary College, University of Guelph, Guelph, Ontario N1G 2W1.

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Table I. Direct and indirect determinations of blood pressures (mm Hg) in anesthetized dogs[a]

Plane of anesthesia	Light		Deep	
Method of measurement	Direct	Indirect	Direct	Indirect
Systolic	96.7 ± 2.1 (67–130)	98.9 ± 2.6 (72–126)	53.9 ± 2.1 (41–87)	64.3 ± 2.7[b] (43–96)
Diastolic	71.0 ± 3.1 (41–95)	61.4 ± 3.0[b] (31–99)	35.6 ± 1.9 (21–62)	32.5 ± 1.6 (17–52)
Mean arterial pressure	83.5 ± 3.4 (52–113)	75.3 ± 3.2[b] (39–111)	43.2 ± 2.2 (28–74)	42.4 ± 2.1 (24–69)

[a] Data are shown as mean ± standard error of the mean (range) for 11 dogs. Three measurements per site per dog

[b] Significant difference ($P < 0.05$) between direct and indirect values

Table II. Mean differences between triplicate determinations of direct and indirect determinations of blood pressures (mm Hg) in 11 anesthetized dogs

Plane of anesthesia	Light		Deep	
Method of measurement	Direct	Indirect	Direct	Indirect
Systolic	4.2 (4.3%)[a]	5.4 (5.5%)	5.3 (9.8%)	4.9 (7.6%)
Diastolic	6.7 (9.5%)	7.5 (12.3%)	2.8 (7.8%)	5.9 (18.2%)
Mean arterial pressure	4.1 (4.9%)	10.5 (13.9%)	4.1 (9.5%)	7.4 (17.5%)

[a] Numbers in brackets represent the maximum difference between triplicate determinations as a percentage of the mean blood pressure. Three measurements per site per dog

given IV at 10–15 mg/kg, and were then maintained using methoxyflurane delivered by a circle-type anesthetic machine (Ohio Medical Products, Medishield).

For direct blood pressure measurements, 1 sublingual artery from each dog was catheterized using a 22 gauge 1 inch vialon catheter (Insyte-W, Becton Dickinson Vascular Access, Sandy, Utah), and connected to a pressure transducer (Physio-Control VSM1, Physio-Control, Cardiovascular Division, Redmond, Washington), which had been previously calibrated with a mercury manometer by applying a pressure equivalent of 100 mm Hg to the transducer. A 3-way stopcock was attached to the catheter, the pressure transducer, and a reservoir of heparinized saline. The catheters were flushed with saline prior to, and subsequent to, each direct pressure determination. The measurements were standardized by setting 0 mm Hg at the level of the right heart on each patient.

A disposable neonatal cuff (Critikon Corp., Tampa, Florida), the size of which had been determined by applying the manufacturer's guidelines to the limb circumference, was attached tightly around the left or right midradial area overlying the median artery. The cuff was attached to an oscillometric indirect blood pressure unit (Dinamap 8100, Critikon). The leg was positioned to place the cuff at the level of the right heart. Three measurements each, of systolic, diastolic, and mean arterial pressures, were made on each dog at both light and deep surgical planes of anesthesia. The direct and indirect measurements were made simultaneously. The light anesthetic plane was the anesthetic plane judged to be safe by clinical observation without the use of blood pressure monitoring. The surgical plane of anesthesia was adjusted (to a deep plane) by increasing the concentration of delivered inhalant until an appropriate fall in direct blood pressure was achieved; a difference of 20–30 mm Hg was the goal. The patients were stabilized at this deeper plane and simultaneous blood pressure measurements made. At each determination, direct blood pressure stability was present during the 30 s required for indirect determinations or else the measurements were repeated.

The mean of the 3 measurements obtained by direct catheterization of each dog was compared with the simultaneously indirectly obtained mean for the same plane of anesthesia using the paired t-test. This was repeated to compare direct and indirect values for systolic, diastolic, and mean arterial pressures for each dog. Precision of the 2 techniques was assessed by subtracting the minimum from maximum values (range) observed in the triplicate determinations. The largest absolute differences among the triplicate determinations were averaged for groups of dogs for each technique and at each level of anesthesia. These absolute differences were then expressed as the percentage of the mean systolic, diastolic, and mean arterial pressures, for the technique and level of anesthesia. The techniques were compared over all dogs and levels of anesthesia by linear regression analysis. Differences were considered significant if $P \leq 0.05$.

No significant differences were found between direct and indirect systolic pressures at the light plane of anesthesia, direct and indirect diastolic pressures at the deep plane of anesthesia, or direct and indirect mean arterial pressures at the deep plane of anesthesia (Table I). At the lighter anesthetic plane, the indirect determinations of diastolic and mean arterial pressure were significantly lower (13.5% and 9.8% overall, respectively), than the direct determinations; however, at a deep plane of anesthesia, the systolic pressures were significantly higher (16.2% overall) using the indirect method.

The means of the largest absolute differences amongst the triplicate determinations in indirect measurements tended to be slightly higher than direct measurements (Table II); the range of absolute differences for both techniques was 2.8–10.5 mm Hg. The percentage difference in indirect determinations for diastolic and mean arterial pressures were substantially higher (range 12.3–18.2%) than direct measurements (range 4.9–9.5%), or for systolic pressures using either technique (range 4.3–9.8%).

The regression analysis for the 2 techniques showed excellent correlation ($r = 0.93$) (Fig. 1). Approximately 87% of the variation in the indirect measurements was related to changes observed in the direct measurements. Over all dogs and levels of anesthesia, determinations made using the indirect technique were 4.3 mm Hg higher than those determined directly.

These results indicate that the indirect measurement (Dinamap 8100) provides an accurate representation of the true blood pressure. However, the Dinamap tended to underestimate the true diastolic and mean arterial

pressures at the light plane of anesthesia (at higher blood pressures). The 13.5% and 9.8% underestimation, respectively, although statistically significant, may not be clinically relevant.

Our results are consistent with those obtained by other researchers, who concluded that the oscillometric indirect blood pressure monitors, such as the Dinamap 8100, provide a good estimate of the systolic, diastolic, and mean arterial pressures (1,2,4–11). The slight underestimation by the oscillometric monitors was also consistent amongst investigators. Over the wide range of direct mean arterial pressures that these previous researchers had examined (23–160 mm Hg), and the range that we studied (28–113 mm Hg), the Dinamap adequately demonstrated changing trends in blood pressure. One group (7) concluded that the Dinamap provides reliable trend information, but due to the time required for the Dinamap to inflate and deflate the cuff, and read the systolic, mean arterial, and diastolic blood pressures, it is unsuitable for use in studies involving short-acting drugs. Numerous researchers have investigated the use of different cuff sizes with different cuff width to limb circumference (CW/LC) ratios (1,4,6,7,12). The consensus is that a ratio between 0.4 and 0.6 is optimum, as recommended by the manufacturer (13). Too narrow a cuff overestimates the pressures, while too wide a cuff underestimates or provides erratic pressures readings (4,12).

The 16.2% overestimation of systolic pressure using the indirect technique at a deep plane of anesthesia has also been reported by other investigators (1,10). Inappropriate cuff size and limb movement are the major sources of error when using indirect blood pressure monitors (1,3,4,9,13). Previous studies had used slightly larger dogs than those in our study; however, smaller limb size and slightly different limb shape may affect the results. We followed the manufacturer's recommendations when choosing the cuff size; however, this variable was not evaluated here. Limb movement was not a confounding variable here since the dogs were anesthetized.

The indirect technique had good repeatability at systolic blood pressures. When the maximum absolute difference between triplicates was expressed as a percentage of the mean

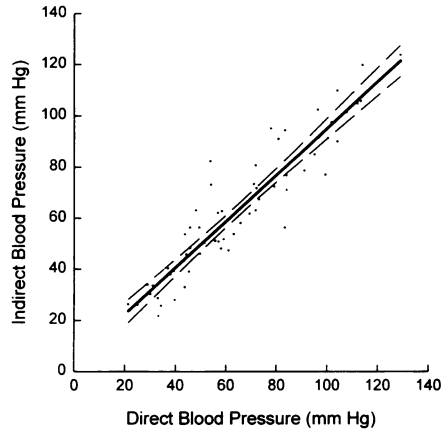

Fig. 1. The linear relationship (solid line) between indirect and direct measurements of blood pressure in anesthetized dogs (n = 11). Dotted lines represent the 95% confidence interval. The regression equation was y = 4.32 + 0.91x; r = 0.93. Data points represent the mean of triplicate determinations.

systolic blood pressure, the precision was similar to the precision observed using the direct method, and was always less than 10%. Thus, at systolic pressures, even a single indirect measurement is a good estimate of the blood pressure.

The percentage differences at diastolic and mean arterial pressures for the direct method were similar to those observed at systolic pressures, but were higher for the indirect technique. These data indicate that multiple indirect measurements may be required to adequately assess blood pressure trends at lower pressures that are seen in diastolic and mean arterial pressure measurements. The small differences noted in direct blood pressure indicated the stability of blood pressure during these measurements.

In conclusion, the indirect technique tends to underestimate diastolic blood pressures and overestimate systolic blood pressures. Overall, the agreement between both methods over a wide range of blood pressures was excellent. Due to the lower precision observed at diastolic pressures, determinations using the indirect technique should be done in triplicate and the mean calculated. Our data also indicate that the indirect technique is appropriate for small dogs (<12 kg).

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